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1408078

(54) A METHOD OF CONTROLLING A MOTION OF A LAND VEHICLE

(71) We, ERNST LEITZ GMBH, of 6330 Wetzlar, Postfach 2020, Federal Republic of Germany, a joint stock company organised under the laws of the Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method and apparatus for measuring, controlling or indicating a motion of a land vehicle in relation to its surroundings.

As soon as the maximum available frictional force between the road wheels of a vehicle and the road is exceeded by braking, the road wheels lose their grip on the road surface. Static friction changes into the lesser dynamic friction, the wheels may become locked and, consequently, the vehicle slides along the road surface. This not only reduces the potential braking deceleration but also the available lateral steering force, so that the vehicle becomes virtually uncontrollable and skids. The risk of skidding is particularly great when the co-efficient of friction between the wheels and the road surface is small, which happens on a slippery road or on an icy street.

When a vehicle is braked a certain slip always develops due to deformation of the tyres on the wheels of the vehicle, since the circumferential speed of the wheels is smaller during braking then the speed of the vehicle. Maximum adherence to the road prevails at slips between 10 and 30 per cent depending on the properties of the tyres and the road. On the other hand when the wheels are completely locked the slip is 100 per cent. The lateral steering force drops continuously to zero as the slip increases but is still quite high at slip values between 10 and 30 per cent. Therefore the purpose of an anti-locking mechanism is to control the braking power of a vehicle so as to develop the optimum slip whatever the force applied by the driver on the brake pedal. Best results are obtained when the road wheels are controlled independently of each other.

It is known to measure the actual vehicle speed by using apparatus such as a non-braked freely rotating fifth wheel, or a centrifugal disk. However, such apparatus is both complicated and expensive. This is why the now adopted criterion for establishing the start of skidding is the angular deceleration of the wheel which occurs at this instant. This deceleration is due to the fact that during the transition into the skidding condition the braking power is no longer applied to the bulk of the vehicle mass, but merely upon the much smaller mass of the wheel. On the other hand, the wheel itself is subject to acceleration when, after a sudden release of the brake, the wheel is again free to rotate. In a known protection system against skidding of this kind each wheel is provided with an inductive pulse emitter for sensing the speed of rotation of the respective wheel.

The disadvantage of such known apparatus is that data on vehicle movements are derived indirectly by measuring acceleration. Its relationship to vehicle speed is necessarily incorrect since distorting factors such a tyre pressure, oscillations, vehicle loading entail errors in the measurements.

Another most important factor in improving traffic safety is the knowledge of the distance to the vehicle next ahead and the generation of warning and control signals as soon as this distance is reduced below a pre-

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(19)

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(54) A METHOD OF CONTROLLING A MOTION OF A LAND VEHICLE

PATENTS ACT 1949

SPECIFICATION NO 1408078

Reference has been directed, in pursuance of Section 9 subsection (1) of the Patents Act 1949, to Specification No 1389309.

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tion to its surroundings.

As soon as the maximum available frictional force between the road wheels of a vehicle and the road is exceeded by braking, the road wheels lose their grip on the road surface. Static friction changes into the lesser dynamic friction, the wheels may become locked and, consequently, the vehicle slides along the road surface. This not only reduces the potential braking deceleration but also the available lateral steering force, so that the vehicle becomes virtually uncontrollable and skids. The risk of skidding is particularly great when the co-efficient of friction between the wheels and the road surface is small, which happens on a slippery road or on an icy street.

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determined safe distance related to the speed of the following vehicle. Known systems functioning without recourse to auxiliary means mounted along the road have basic disadvantages. Because of the linear propagation of rays serving to measure the distance (e.g. infra-red beams, radar, Laser beams, etc.) no distance measurements can be effected when travelling along curves or over undulations in the road surface. There is also the risk that oncoming traffic, trees, kerbs, bridges will falsify measurements.

According to one aspect of the present invention, there is provided a method of measuring, controlling or indicating a motion of a land vehicle, comprising the steps of forming at least one image of an object in the vicinity of the vehicle on an optical grating of an optical correlator device, deriving a pair of phase-opposed electrical signals from at least one photo-electric receiver responsive to light modulated by the grating, deriving at least one further electrical signal from the phase-opposed signals to represent the motion of the vehicle relative to the object, and applying the or each derived signal to means for measuring, controlling or indicating, respectively, the motion of the vehicle.

Thus, the movement of at least one image of a feature in the surroundings in relation to the vehicle is translated into phase-opposed signals representing vehicle movement by means of an optical correlator device or system including an optical grating and at least one photo-electric receiver. These signals are then separated from signal constituents of the same sign or from distorting signals and then, if necessary, jointly with other other signals derived from other measured values applied as input to a servo system which controls the movements of the vehicle.

To counteract the skidding effect of the vehicle wheels on the ground, the optical correlator system translates movement along the road into signals proportional to the vehicle speed; these signals are then compared with signals related to the speed of rotation of the road wheels of the vehicle; signals resulting from this comparison are then applied to the input of a servo system which controls operation of the vehicle drive means or the vehicle braking means with the object of obtaining a certain optimum slip between the road wheels and the ground.

To control the unwelcome lateral drift with due regard to its sense, an optical correlator system converts the movement of the road transversely to the normal direction of vehicle movement into electric signals proportional to the lateral movement of the vehicle. These signals are obtained either direct as measured in the correlator system and represent the actually measured movement across the direction of normal travel, or are obtained by calculation as the difference between the measured actual direction of vehicle movement and the normal direction. These signals are then applied to a servo system controlling the steering means of the vehicle.

To adjust brakes and the vehicle drive means to the varying travel conditions when negotiating bends in the road, the lateral drift of the vehicle is converted by an optical correlator system into signals representing in magnitude and sign both the movement along the road and motion transversely to the intended travel direction; these signals are combined with other signals, preferably proportional to the vehicle speed, to the vehicle slip in the direction of travel, and proportional to the deflection of the steering means, and then applied to the driving or braking system, or to a servo system to adjust the steering. These signals also serve for current indication of the difference between the maximum permissible and actually prevailing curve negotiating speed.

To measure the distance between vehicle and an obstruction in its path, an image structure of the obstruction is registered by at least one optical correlator system which emits signals relating to the distance, relative speed in the direction of vehicle movement, and the relative speed transversely to the path between the vehicle and the obstruction; these signals are then compared with the speed of the controlled vehicle over the ground, and the resulting differential signals are applied to a servo system causing the speed of the controlled vehicle to change, and/or to operate an indicating and/or warning appliance.

The signals for distance, or distance change, are derived from the amplitudes of signals derived from the correlator system; signals for the relative speed transversely to the travel direction are derived from frequency and phase displacement of the signals derived from the correlator system.

To assess the speed of vehicles approaching the rear of the controlled vehicle, at least one image structure of the trailing vehicle is evaluated in an optical correlator system directed towards the rear of the controlled vehicle; in addition the correlator system generates electrical signals proportional to the approach speed of the vehicle at the rear and to its distance. These signals are compared with the speed of the controlled vehicle and the comparator output applied to an indicating and/or warning appliance.

Preferably, the method is characterised by the use of an optical correlator system with at least one optical grating in an image plane and of at least one photo-electric receiver responsive to light modulated via the or each grating: the system may comprise further means for mechanical movement of an opti-

cal unit or units which polarize or split the light into colours, or means for moving two gratings or grating structures, which in conjunction produce signals containing the necessary information.

Additionally, the method may be characterised by the use of an optical correlator system comprising in an image plane an optical grating comprising strip type photo-electric receivers.

According to a further aspect of the present invention, there is provided apparatus for measuring, controlling or indicating a motion of a land vehicle relative to an object, comprising an optical correlator device mounted on the vehicle, the correlator device including an optical grating and at least one photo-electric receiver responsive to light modulated by the grating, imaging means to form at least one image of the object on the grating, means for deriving a pair of phase-opposed electrical signals from the correlator device, means for deriving at least one further electrical signal from the phase-opposed signals to represent the motion of the vehicle relative to the object, and means for applying the or each derived signal to means for measuring, controlling or indicating, respectively, the motion of the vehicle.

Preferably, apparatus for carrying out the method is characterised by: the provision preferably for each vehicle road wheel of a sensor-transmitter of their rotational speed; the provision of a correlator system generating signals containing directional and sign-true information which measures the relative speed of the vehicle chassis in relation to the ground without any contact therewith, the correlator system comprising at least one grating in an image plane and at least one photo-electric receiver associated with the grating and receiving light energy modulated by the grating, and comprising, if necessary, additional means for mechanical movement of at least an optical unit or means which polarize or split light into their colour fractions, or means for appropriately moving two grids or grid systems; the provision on the load side of the correlator system of a comparing stage with a preferably adjustable slip set value to which are applied the output signals of the correlator system, the output signals of the comparing stage being if necessary passed through an amplifier and then applied as control signals on to a servo system which regulates the circumferential speed of the respective road wheel.

Advantageously, the apparatus comprises at least one optical correlator system generating signals containing directional and sign-true information which measures movement transversely to the normal travel direction of the vehicle, the correlator system comprising at least one grating in an image plane, at least one photo-electric receiver associated with the grating and receiving light energy modulated by the grating, optical means to polarize or split light into its colour fractions, and means for displacing either the grating system or the optical means; the provision on the load side of the correlator system of a comparing stage to which are applied the sign-true output signals of the correlator system and onto which if necessary the set value is applied for comparison; and the provision of a servo steering system connected to the output means of the comparator.

Expediently, the apparatus is characterised by: the provision preferably for each vehicle road wheel of a sensor-transmitter of its rotational speed; the provision of an optical correlator system generating signals containing directional and sign-true information which measures vehicle movements both transversely to, and in the direction of vehicle travel, the correlator system comprising at least one grating in an image plane and at least one photo-electric receiver associated with the grating and receiving light energy modulated by the grating, and comprising, if necessary, additional means for mechanical movement of at least an optical unit or means which polarize or split light into their colour components or means for appropriately moving two gratings or grating systems; means for applying the output signals of the correlator system together with the signals from the rotation speed sensor-transmitter to a computer on the load side of the correlator system which calculates the resultant of the lateral thrust slip and slip in the travel direction; the provision of means for comparing the resultant with a set limit value with due regard to the deflection angle of the road wheels of the vehicle; the provision of a servo system which when the resultant exceeds the set value operates the drive or brakes of the wheels and/or the vehicle steering system; and the provision if so required of indicating and/or warning means in the computer output.

Preferably, the apparatus is characterised by: the provision of an optical correlator system generating signals containing directional information which measures movement in the direction of travel preferably along two co-ordinates, the correlator system comprising at least one grating in the image plane and at least one photo-electric receiver associated with the grating and receiving light energy modulated by the grating, and comprising, if necessary, additional means for mechanical movement of at least an optical unit or means which polarize or split light into their colour fractions or means for appropriately moving two gratings or grating system; wherein the output electrical signals and their changes emitted by the correlator system and obtained by using the perspective object image along two co-ordinates each perpendicular to the direction of vision are

applied on to a comparing station connected to the load side of the correlator system; wherein the comparing station comprises a summating stage, a differential stage and/or a ratio determining stage; wherein on the load side of the comparing station a computer is connected supplied in addition with signals from a distance measuring system; and wherein the computer output is connected to a servo system controlling the travel speed of the vehicle and/or an indicating and/or a warning appliance.

Advantageously, the apparatus is characterised by: an optical correlator system facing towards the rear of the vehicle and comprising at least one grating in an image plane and at least one photo-electric receiver associated with and receiving the light modulated by the grating; the electric output signals from the correlator system being applied, together with electric signals proportional to the speed of the controlled vehicle, to a comparing unit the output of which is applied to a warning appliance.

Instead of a grating and the photo-electric receiver associated therewith, apparatus with a single co-ordinate correlator system may be provided with alternately arranged strip shaped photo-electric receivers arranged in a mesh formation.

Embodiments of the invention will now be more particularly described with reference to the accompanying drawings, in which:—

Fig. 1 shows apparatus for measuring and evaluating slip in the direction of travel;

Fig. 2 shows a diagrammatic representation of the apparatus shows in Fig. 1;

Fig. 3 shows a single co-ordinate optical correlator system in accordance with one embodiment of the invention;

Fig. 4 shows a single co-ordinate optical correlator system in accordance with another embodiment of the invention;

Fig. 4*a* shows a variant of the correlator system shown in Fig. 4;

Fig. 4*b*, 4*c* show two views of a part of the correlator system shown in Fig. 4*a*;

Fig. 5 shows a single co-ordinate optical correlator system in accordance with a further embodiment of the invention;

Fig. 6 shows an optical correlator system in accordance with yet another embodiment of the invention;

Fig. 7 shows apparatus for reducing the extent of unwanted changes in the travel direction;

Fig. 8 shows apparatus for adjusting the operation of brakes and drive means in accordance with varying travel conditions while negotiating curves;

Fig. 9 shows a two co-ordinate optical correlator system with a single grid in accordance with a still further embodiment of the invention;

Fig. 10 shows a variant of the correlator system shown in Fig. 9;

Figs. 11*a* to 11*g* show, respective sketches to illustrate the operation of counter-collision apparatus; and

Fig. 12 shows a diagrammatic representation of apparatus provided with a correlator system to prevent collision with an obstacle located in the direction of vehicle travel.

Fig. 1 shows an optical speed correlator device 10 mounted on a vehicle chassis to point downwardly towards the road and serving to measure the forward travel speed of the vehicle. Thus, the device 10 enables the road speed of the vehicle to be measured without employing any sensor members which contact the surface of the road. On each of the four wheels of the illustrated vehicle a revolution sensor-transmitter 30—33 is mounted; their output signals together with the output signals of the correlator system 10 are applied to the intake of a comparator 26 which itself controls a servo system 29, accommodated in the same housing as the comparator 26, and operating the four brake control valves 17, one for each braked wheel. These valves are mounted in pipeline system 12 connected with a main brake cylinder 11 of the hydraulic braking system of the vehicle. The servo system 29 controls, in addition, the differential gear 13 of the traction wheels.

In use, the apparatus described above performs the following function: when braking pressure exceeds a preset threshold, as the brake pedal 14 is depressed, the brake servo system operates the brake control valves and varies the brake pressure applied upon each wheel until the preferably adjustable slip comparing stage 26 assumes the set value between wheel and road resulting from the difference between the wheel transmitter 30—33 signals and the correlator device or system 10. If the preset rotation speed difference of both traction wheels is exceeded, the servo system transmits, independently of the braking system, the driving force via differential gear 13 on to the slower running road wheel.

The construction of the apparatus is indicated diagrammatically in Fig. 2, in which components corresponding to those which have been described in Fig. 1 are indicated by the same reference numerals as those used in Fig. 1.

Fig. 3 shows a single co-ordinate optical correlator device of the kind represented in Figs. 1 and 2 by the reference numeral 10. In Fig. 3 an object in the vicinity of the vehicle, e.g. the road surface, is indicated by the reference numeral 1. This object is illuminated by lamp 2 through condenser 3. The object lens set 4 projects the road image on to the plane of an optical grating 5. A Wollaston prism 16 mounted between two pairs of the object lenses 4 projects, by double refraction, two images of a feature of the

object into the plane of the grating 5. These two images are differently polarized and are mutually displaced in the grating plane 5 by half the grating constant, and each image extends at right angles to the mesh of the grating 5. The light derived from the respective images is then transmitted, after passing through the grating 5, through a polarizing divider 7 and condensers 9, to respective ones of photo-electric receivers 8.

Since different features of the object surface (as indicated on object 1 by dark patches) absorb light differently, the output signals from the photo-electric receiver 8 vary in amplitude in correspondence with the changes in light strength distribution in time on the plane of the grating 5 due to movement of the vehicle relative to the object 1. By superimposing the object structure and the optical grating structure, the image components are filtered and their local frequency is related to the grating constant. During this process, additional low frequency image constituents pass through the grating and represent a distorting fraction with the same light intensity on each receiver. The same applies as well to the image displaced by half the grating constant, the only difference being that the local waveform related to the grating constant is shifted in phase by 180° against that of the first-mentioned signal. By a subsequent substraction of electrical signals derived from both images, all co-phase, equally illuminated light components are eliminated and the signal components with the opposite sign to the filtered local waveform are added. When the object is moving relative to the vehicle, or vice-versa, this local frequency is converted into a frequency proportional to speed, and is then measured.

It is of course possible when the object is stationary to move the grating 5 in relation to the optical axis of the apparatus (the drive means for effecting such displacement of the grating 5 is indicated schematically at 15). If this is done e.g. uniformly in one direction the receiver output for a stationary object has a frequency proportional only to the speed of movement of the grating 5. Contrary thereto, when the object is moving, the frequency depends on the direction of movement and is proportional either to the sum or difference of grating and object speeds. From these signals it is then possible by comparing them with a signal generated from the movement of the grating alone (e.g. by means of a phase-sensitive rectifier) to determine the magnitude and direction of the vehicle movement relative to the object, and vice-versa.

When determining the local position, it is necessary to count the number of emitted periods in the comparator output, with due regard to the also available directional information.

In the optical correlator shown in Fig. 4 the reference numeral 1 represents an opaque object moving relative to the vehicle; its relative speed is to be measured under incident light. Object 1 is illuminated by lamp 2 through condenser 3. The object lens set 4 projects the object image on to the plane of an optical grating $5a$ which is in the form of a grooved optical grating structure with a triangular section of grooves $5'$. Because the faces of the grooves $5'$ have mutually different slopes an energy split is effected due to different light direction changes from adjacent faces. The energy from each refracting face-set is then transmitted through condensers 9 to one of the two photo-electric receivers 8 respectively.

Since the object surface pattern as shown on object 1 by darker areas absorbs incident light differently at each point, the respective output signals of the photocells 8 have different components corresponding to the changes in time of the brightness in grating plane $5a$ due to the relative movement of object 1. Superimposition of the surface pattern of object 1 with the grating shape causes fractions of the image pattern to be transmitted via the grating with a local frequency equal to the grating constant. At the same time, some additional low frequency components of the light from the image pass through the grating and constitute a disturbing part of the signal with the same light intensity on each receiver. The same applies to the image points displaced by half the grating constant, the only difference being that the local frequency corresponding to the grating constant is displaced in phase by 180° in relation to the first mentioned local signal. With the help of a difference forming operation applied to the electrical signals obtained from both image fractions, the constituents of these signals due to the co-phase uniform light intensity are eliminated. At the same time, the signal constituents in the signal fractions after filtering are combined or summated with the counter-phase signal fractions. When object 1 is moved in relation to the grating, the local frequency is then converted into a signal of which the frequency is proportional to the speed of movement, and the frequency of this signal is measured.

Optical grating $5a$ is movable in the direction of the adjacent double-head arrow. An electrically operable drive unit 15 to effect this movement is shown in Fig. 4 by broken lines and serves to move the grating periodically in relation to the optical axis. When this is done, an alternating signal is obtained at the receiver output while the object is static; depending on the direction in which the object is moved, the frequency of this output signal is proportional to the sum or difference of the speeds at which object and grating are moved.

With the help of these signals it is then

possible to determine the magnitude and direction of the object movement by comparing them with a signal generated by the movement of grating alone (e.g. with a phase-sensitive rectifier).

The object 1 may comprise part of the surface of a road, in relation to which the correlating system is displaced as the vehicle on which it is mounted moves along the road.

In Fig. 4*a* another correlator device is shown. Reference 1 denotes again the moving opaque object; its movement relative to the correlator device is to be measured. Object 1 is illuminated by lamp 2 with condenser 3. The object lens set 4 projects an image on to the plane of a grating 5‴. Fig. 4*b* is a plane view on grating 5‴. This grating consists of a plurality of strips which are either transparent, polarizing, or opaque. The strips are arranged in such an order that a linear polarizing strip is followed by an opaque strip, a strip polarizing at right angles to the first polarizing strip, a transparent strip, etc. in a periodically repeated sequence. This grating structure can be regarded as a superimposition of two plain linearly polarizing strip gratings polarizing at right angles to each other and displaced mutually by a quarter period. The light from the object image is then transmitted, after being filtered via grating 5‴, through a polarizing ray divider 7 suited to the optical characteristics of the grating and condensers 9 to two photo-electric receivers 8.

The above described appliance performs the following function: each of the two photo-electric receivers 8 is sensitive only to light transmitted *via* one grating 5‴ strip structure displaced to each other by a quarter period. When the measured object 1 is moved transversally in relation to the optical axis, the output signals from the receivers 8 consists of periodical electric signals displaced in phase by 90°. They serve to determine the directional speed and position of the measured object 1.

The grating 5‴ can, as shown in Fig. 4*c*, be designed with division carriers for different polarization, shown by different shading. These are superimposed in a specific arrangement of their dividing action and fixed in a definite position corresponding to the arrangement of strips shown in Fig. 4*b*.

It was found that quality of signals emitted by the correlator system can be vastly improved in that the momentary object elements, which contribute mainly to the generation of signals and enable the measurement of the high local frequency, are made to yield sharper images than the other elements of the structure. This can be achieved e.g. by mounting a slit diaphragm (or a cross-slit diaphragm for measurements along two co-ordinates) in the ray path of the correlator intake, preferably in the aperture zone or in the co-focal zone of the image generating part of the system. The diaphragm is arranged so that the longitudinal centre line of each slit is positioned at right angles to the measurement direction at the grating. It was found that provision of a slit diaphragm improves quality of the signals three-fold and even more. For this purpose diaphragm 6 is mounted in the optical lens set 4; the slits are parallel with the strips of the grid 5‴, as shown along-side the optical axis in Fig. 4*a*. The diaphragm performs the following functions:

Accuracy of movement measurements by means of the optical correlator system depends on the object surface pattern and on the way its image is obtained; this is determined by the signal amplitudes. Information relating to movement along one co-ordinate is based on statistical changes of this pattern in the direction of measurement. The surface pattern at right angles to the direction of measurement and its statistical changes produce distorting signals affecting measurement of useful signals. This transverse structure effect cannot be completely suppressed however because in order to optimize the transmission of light energy, a two-dimensional object image is preferred in which some oblique rays are reproduced with the help of a rotationally symmetric optical unit. Optimizing is achieved by using diaphragm 6, which serves to increase sharpness of the image depth in the direction of measurement.

With the help of the unit shown by broken lines it is further possible to obtain besides the above described signals also counter-phase signals to suppress the disturbing signal components with the same phase direction as the useful signals. For this, a colour splitting prism 16′ positioned between the object lenses 4 produces by dispersion two object images which are mutually displaced in the grating plane by half the grating constant, at right angles to the grating strips. The light from each image is carried through a colour divider 7″ to each photo-electric receiver-pair 8 and 8′. In addition, a polarizing divider 7′ and condensers 9′ suited to the grating 5‴ are provided. Due to the displacement of both colour images, the respective output signals derived from the receivers 8 and 8′ consist of signals displaced in phase by 0°, 90°, 180° and 270° which are processed further.

In Fig. 5 a correlator system is illustrated in which the optical grating comprises two strip-shaped photo-electric receivers 8′ and 8″ on carrier 5*a* in which the strips are connected in an interlocking pattern as indicated in the drawing. The longitudinal strips of receivers 8′ and 8″ are alternately connected at their ends to transverse strips; the output

signals of these receivers are connected in opposite polarity to obtain differential signals. Otherwise this arrangement is similar to that which has been described with reference to Fig. 4. When the grating is moved by the electrically operable driving unit 15 electrical signals are generated in both receivers which operate in counter-phase. If object 1 is moved simultaneously the frequency of the signals is modulated; from this, the magnitude and direction of the object speed can be determined.

Fig. 6 shows by way of example an alternative spatial arrangement of the optical correlator system. At the top of a tubular housing 18 an optical correlator 10′ and an illumination unit 2 are placed side by side which constitute jointly the correlator system. Both are enclosed in the direction downwards to the housing bottom end 18 by optical units 3′ and 4′. The interior of the tube 18 is so supplied through a feed pipe 20 with compressed air or other gas that the sealing flap 22, mounted below the units 3′ and 4′ and balanced by a counter-weight 21, is opened by the air current and, thus does not obstruct the light paths. Compressed air may be produced e.g. by the pressure developing by the movement of the vehicle or the motor fan. In some applications it may be desirable to pre-heat the air before it is introduced into the housing.

A speed correlator system 10 shown in Fig. 7 is arranged, contrary to the correlator systems described above, to react sign-true to the travel speed component at right angles to the direction of travel. The output signals from the correlator system 10 are applied together with the signals from the steering wheel 23 operated angle transmitter 24 to a comparing stage 29. When the comparing stage reacts to the lateral speed component which deviates from the desired direction to travel as intended by turning the steering wheel, the servo steering system 26 connected to the output is automatically operated in such a way that the vehicle is brought into the desired direction of travel. When the correlator system 10 is mounted for direct control from the steering wheel 23 and always brought into the desired travel direction, then no angle sensor-transmitter 24 is needed.

Fig. 8 illustrates a speed correlator system 10′ serving to measure simultaneously the speeds along two mutually perpendicular co-ordinate directions, one in the travel direction and the other at right angles thereto; its output signals are applied jointly with the signals from the wheel revolution sensor-transmitters 30; 33 and the angle sensor-transmitter 24 to computer 25′. Computer 25′ calculates the correction magnitude with duc regard to the steering deflection of the vehicle road wheels signalled by the steering servo unit 26. If this calculated value of the correction exceeds the preset limit, computer 25′ emits corresponding signals into the servo system 26′. The correction is always subtracted from the resultant constituted by the forward slip and lateral drift. The servo system controls in the illustrated case the engine, brakes on the wheels and the steering servo unit 26 until the limit value again exceeds the measured value. Even before the servo system begins to operate, a warning device 28 is switched on. It is also possible to provide continuous monitoring by means of an indicator device controlled by the computer.

This correlator system taking measurements along two co-ordinates is shown in Fig. 9. The relative speed of the object denoted 1 is measured. Object 1 is illuminated by lamp 2 through condenser 3. An object lens set 4 projects the object image on to the plane of optical grating 25. Grating 25 comprises a carrier 5*a* with a plurality of identical adjacent pyramids 5″ with contacting parallel base edges. Two directional pairs of the light rays are defined in the grating plane by the projections of normals to the pyramid faces. These are provided with four photo-electric receivers 8 and four condensers 9. Since the surface pattern shown on object 1 by differently shaded areas reflects light of varying intensity, the output signals of photo-elements 8 contain variable light components corresponding to the change in time of the brightness distribution in the grating plane 25 because of the relative movement of object 1. By superimposing the object pattern with the grating structure certain wanted image light components are filtered out with a local frequency related to the grating constant. At the same time, however, additional low frequency image light components are modulated by the grating as unwanted uniform light constituents. By the described grating layout it is possible to obtain, for each co-ordinate direction, a pair of signals in counter-phase. By deriving the difference for each pair of signals the co-phase uniform light components are eliminated and the counter-phase signal components with the filtered local frequency added. When the object moves in relation to the grating, this local frequency is converted into a signal of which the frequency is proportional to the speed of the vehicle relative to the imaged object. As shown in Fig. 9, a drive unit 15 may be provided which shifts the movably mounted grating 25 at right angles to the optical axis and preferably in the direction of the grating element-diagonals. If this is done, an alternating signal is obtained even when the object is stationary in relation to the correlator device. The frequency of this signal is proportional either to the sum or to the difference between the object speed and the grating speed, depending on the direction of object movement.

With the help of these signals it is possible to determine both magnitude and direction of object movement by comparing the signals with a signal obtained when only the grating is moved (e.g. by means of a phase-sensitive rectifier). When the local position is measured, the number of continuous periods at the comparator output is counted with regard to the directional information which is also available. It is also possible to replace the several photo-electric receivers which each measure data along one co-ordinate, by a single photo-electric receiver provided, for example, with an oscillating mirror to reflect alternately the rays emitted by the grating in both directions. The quality of the signals from the correlator system can be improved by selecting certain structures existing at the object surface which contribute most to the generation of signals and have large local frequency components in the direction of measurement by using them in preference to other object structures. This principle is embodied in apparatus for making measurements along two co-ordinates, and shown in Fig. 10. The road surface 1 is illuminated by lamp 2 with condenser 3. The object lens set 4 produces an image of a feature of road surface in the plane of a pyramid shaped optical grating 25. Behind the entry lens of the objective set 4 a cross diaphragm 6′ is provided with slits parallel to the pyramid face inclination in grating 25 and therefore parallel to the measured directions. The light passing through grating 25 then passes through a common condenser 32 to each of the photo-electric receivers 8, arranged in pairs. The signals leaving the receivers are then processed in the same way as with the apparatus shown in Fig. 9. It was found that by using this layout the signal quality is improved threefold and more.

Instead of generating directional signals by means of the driving unit 15 which causes the grating 25 to oscillate in the direction of its diagonals, a stationary arrangement can be used. In this case the grating is mounted statically and, in the incident ray path, a polarizing divider (e.g. a Wollaston prism) is mounted to effect division in the direction coinciding with a diagonal of the grating.

Instead of the apparatus described with reference to Figs. 9 and 10 it is possible to use two appliances for measuring in the direction of one co-ordinate each instead of a single appliance measuring along two co-ordinates. These two single co-ordinate appliances are then appropriately positioned in relation to the measured direction and preferably covering the same light components emitted by the object surface 1. The optical correlator systems for effecting measurement along one co-ordinate are shown in Figs. 3 to 5.

With the help of Figs. 11*a* to 11*g* we shall now explain the principle of distance measurement. It is known that by means of units for measuring distances alone it is not possible to solve problems relating to distance measurements for moving vehicles; in this case the distance to obstructions are also measured which are beyond the collision course (e.g. vehicles travelling in the opposite direction in their traffic lane, road kerbs along curves, etc.). For this reason it is necessary to derive additional information which produces data on the approach speed and the lateral movement of obstructions. In Figs. 11*a* and 11*c* an obstruction in the form of another vehicle is shown positioned on the collision course. As indicated by a comparison between Fig. 11*a* and Fig. 11*c*, the image of the obstructing vehicle is disposed symmetrically with respect to the chain-dotted lines, which represent the two axes of symmetry of the field of vision, and the image of the obstructing vehicle becomes progressively larger as the vehicle carrying the optical correlator approaches the obstructing vehicle. However, when an obstruction is disposed to one side of the path of the vehicle carrying the correlator, the progressive enlargement of the image of the obstruction is associated with a simultaneous lateral displacement of the image, as indicated by comparing Fig. 11*d* with Fig. 11b, where the obstruction is another vehicle, which is being overtaken.

The rate of enlargement of this image is related to the speed at which the vehicle approaches the object imaged, and to the distance between the object and the vehicle. Also, the lateral displacement of the image is related to the distance and lateral speed of the obstruction. The ratio of both speeds enables us to decide, apart from the size of and distance from the obstruction, the question whether there exists a risk of head-on collision or not.

When for instance a road bend is negotiated, the road kerb facing the vehicle will be registered as an obstacle at a certain distance in the line of vision (and thus in the direction of travel). The image will move however with a certain lateral speed out of the field of vision, Fig. 11*e*. The approach speed v_a is a component of the relative movement and the lateral movement speed v_s indicates to the observer that there is not risk of a head-on collision.

It may be seen from these considerations that the appliance must also register, apart from the distance and its change in time (the approach speed), the lateral movement of the image in relation to the optical axis coinciding with the direction of travel.

It is therefore also necessary to project an image in the screen field by means of an object lens facing the direction of travel. The

image moves across the screen field in agreement with the angular speed. Objects which during travel along a straight line are located exactly in the direction of travel and perform no movement of their own have no angular image speed. This means that in relation to the field of vision along the optical axis there necessarily exists a point without a relative lateral movement. The greater the angle of rays causing an image to appear in the travel direction, the greater becomes at a given distance and relative speed the angular speed and thus the speed at which the point of an image travel across the field of vision.

If an image projected on to the screen by an object lens is halved by a vertical straight line, as shown in Fig. 11*f*, which passes through the "fixed point" depending on travel direction, then (and only then) the image parts at a distance x to the right and left of this line cutting the image into two will move out at the same and opposite speed and direction (or towards each other if the object is receding) provided no lateral movement exists, that is;

$$| v_r | = | v_e |$$

At a given distance and approach speed, the magnitude of v_r and v_e increases with x because of the described relationship between the angular speed and the angle between the direction of travel and the line of vision. If an image speed meter be mounted at distance x to the right or left of the angle bisecting line which measures the image speed in direction x, then it would be possible to determine from the magnitude and sign of the measured image point displacement speed (by a simple averaging of the summary signal), the approach speed and from the calculated difference also the lateral speed.

Were it necessary for purposes of energy measurement to mount a large area image speed meter into each half of the image, the speed-relationship with the x-value will cause a disturbance only if we mount into the optical correlators for this purpose linear divided local frequency filters. If however, for instance, shaped non-linear periodic period spacing units were adopted, it would be possible to obtain over a range of magnitudes for x signals of the same order for a certain approach speed

$$(v_{r2} = \text{approx. } v_{r1} \cdot \frac{x_2}{x_1})$$

If the image is further halved not only in the direction x but also along y again by drawing a straight line intersecting horizontally the "fixed point" the same considerations will apply per analogy as described above. In fact, however, the image points always move radially away from the "fixed point".

This means that for the purpose on hand the optimum pattern is obtained with circular non-linear arc spacings similar to the Fresnel zone plate or with suitable sections thereof which serve as local frequency filters, Fig. 11*g*.

With ground vehicles only one lateral movement generally occurs, i.e. a displacement in one dimension. Therefore only two image speed sensors are needed in the field of vision. For other applications it is naturally possible to use sensors for a second co-ordinate and then determine from all four sensor signals the direction of a transverse movement in all four quadrants.

Fig. 12 shows diagrammatically the layout of a passive anti-collision apparatus based on the considerations discussed above. Fig. 12 shows a speed correlator system 10''' for taking measurements in all four quadrants; its output signals for one co-ordinate are applied to a summating stage 34 or 34' and a difference-forming stage 35 and 35'. The output signals from these stages are applied to a ratio evaluating unit 36 which correlates the sum and differential signals for one co-ordinate and ascertains their ratio. A computer 25' is also provided on the load side of the evaluating unit. Associated with this correlator system is a distance measuring system 27. Its output signals are also applied to the computer 25'. The output signals of this computer can be evaluated in different ways as indicated above. First, it is possible to feed these signals into a servo system 26'' which reduces the speed of the controlled vehicle until its speed is less than or equal to the speed of the oncoming vehicle. If on the other hand the registered object is motionless, the controlled vehicle is braked. Moreover, each such servo system is provided with an indicator 40 and/or an alarm 28' which emits a suitable warning of the detected danger.

It is an advantage to position both measuring systems 10''' and 27 behind the windscreen of the vehicle to protect them against weather.

The advantage of the anti-collision apparatus compared with known systems consists in that the obstructions along the collision path can be perfectly well distinguished from other obstacles (e.g. road kerbs) since they do not generate an asymmetric signal component in the measuring system.

By using photo-electric receivers reacting to infra-red rays, it is possible to generate signals induced by a vehicle travelling in front in the dark and when its rear lights are out of order.

When the approach speed of a vehicle travelling in the rear is to be detected by the proposed method, an appliance as described is

used comprising an optical correlator system with at least one optical grating structure in its image plane and at least one photo-electric receiver. The electric output signals of the correlator system are then applied to a comparing unit together with electric signals proportional to the speed of the controlled vehicle. The comparing unit output is then applied to an alarm.

It is an advantage to provide each vehicle with two optical correlator systems; one effects measurement along two co-ordinates and is mounted at the front end of the vehicle; the second correlator system positioned at the rear of the vehicle measures only in the direction at right angles to the direction of travel. This layout is necessary for early detection of the rear skid.

It should be finally mentioned that for measurements along the road surface the correlator system should be provided with an optical system suitable for taking into account distance variations and provide it with an auxiliary distance-effect-compensating system which ensures that the image position remains approximately the same. If necessary, the adjustment of this optical unit is controlled by a distance measuring system.

Although, in each of the embodiments which have been described above to photo-electric receivers are shown to evaluate movement in the direction of a co-ordinate it is often possible by adopting appropriate means to replace the two receivers by one such receiver which is alternately moved into the required ray path of the system. This avoids differences in the working characteristics of several concurrently used photo-electric receivers.

Also, although the invention has been described with reference to its application to a land vehicle supported on road wheels, the invention may also be applied to tracked vehicles.

WHAT WE CLAIM IS:—

1. A method of measuring, controlling or indicating a motion of a land vehicle, comprising the steps of forming at least one image of an object in the vicinity of the vehicle on an optical grating of an optical correlator device, deriving a pair of phase-opposed electrical signals from at least one photo-electric receiver responsive to light modulated by the grating, deriving at least one further electrical signal from the phase-opposed signals to represent the motion of the vehicle relative to the object, and applying the or each derived signal to means for measuring, controlling or indicating, respectively, the motion of the vehicle.

2. A method as claimed in claim 1, comprising the steps of deriving a first signal proportional to the speed of the vehicle from the phase-opposed signals, generating at least one second electrical signal proportional to the peripheral speed of a respective rotary or circulatory member supporting the vehicle on the ground, comparing the first signal with the or each second signal, and applying at least one electrical control signal resulting from this comparison to control means of the vehicle to initiate acceleration or deceleration for the purpose of achieving a predetermined difference between the speed of the vehicle and the peripheral speed of the respective supporting member.

3. A method as claimed in either claim 1 or claim 2, comprising the step of generating at least one electrical signal proportional to movement of the vehicle in a direction transverse to a desired direction of travel of the vehicle, and applying the or each said signal to steering means of the vehicle.

4. A method as claimed in claim 3, wherein the or each signal proportional to movement of the vehicle in a direction transverse to the desired direction is derived from the phase-opposed signals.

5. A method as claimed in claim 1, wherein for the purpose of adjusting the braking means and drive means of the vehicle to varying travel conditions when traversing a curved route, electrical signals proportional to the movement of the vehicle transverse to the desired direction of travel are derived from the optical correlator device, and these signals are applied to the drive means, braking means or to steering means of the vehicle, the signals providing an indication of the maximum permissible and actual speed of the vehicle along a curve.

6. A method as claimed in claim 5, wherein further electrical signals relating to the vehicle slip in the direction of travel and to deflection of the steering means of the vehicle are derived, at least one of the further signals, in combination with the signals proportional to the movement of the vehicle transverse to the desired direction of travel, being applied to the drive means, braking means, or steering means of the vehicle.

7. A method as claimed in claim 1, wherein for the purpose of measuring distances between the vehicle and an obstruction in the direction of travel, an image structure of the obstruction is received by the optical correlator device, signals are generated relating to the distance, the relative speed in the direction of travel and the relative speed in the direction transverse to the desired direction of travel between vehicle and the obstruction, and these signals after being compared with the speed of the vehicle are applied to a servo system controlling the speed of the vehicle or to an indicating device or to a warning device.

8. A method as claimed in claim 7, wherein the signals for representing distance or its change are obtained from the amplitudes of signals derived from the optical correlator

device, and signals representing the relative speed in a direction transverse to the desired direction of travel are obtained from the frequency and phase angle of signals derived from the optical correlator device.

9. A method as claimed in claim 1, wherein for the purpose of determining the approach speed of vehicles following the controlled vehicle, the optical correlator device is arranged to face to the rear of the controlled vehicle to register at least one image structure of the following vehicle and to generate electrical signals proportional to its approach speed and to the distance between the following and the controlled vehicle, and wherein said signals are then compared with the speed of the controlled vehicle and applied to an indicating device or to a warning device.

10. A method as claimed in any one of claims 1 to 7, wherein signals related to the direction of movement of the controlled vehicle are derived from the optical correlator device, which comprises at least one optical grating in its image plane, at least one photo-electric receiver responsive to light modulated by the grating, optical means which polarize or split light incident on the grating into their different polarizing or colour components of the incident light, and either the grating or the optical means.

11. A method as claimed in claim 10, comprising the step of splitting light incident on the grating into differently polarized beams by optical means.

12. A method as claimed in claim 10, comprising the step of splitting light incident on the grating into different colour components by optical means.

13. A method as claimed in either claim 11 or claim 12, comprising the step of periodically displacing the optical means relative to the grating.

14. A method as claimed in either claim 11 or claim 12, comprising the step of periodically displacing the grating relative to the beams of light incident on the grating.

15. A method as claimed in any one of claims 1 to 14, wherein the optical correlator device comprises a grating including a plurality of photo-electric receivers arranged in the image plane.

16. A method as claimed in claim 15, wherein the grating includes a plurality of interconnected strip receiver elements, the strip receiver elements of the respective photo-electric receivers being arranged parallel to and alternately with one another.

17. A method of measuring controlling or indicating the motion of a land vehicle, as claimed in claim 1 and substantially as hereinbefore described with reference to Figs. 1 to 3, or Figs. 1, 2 and 4, or Figs. 1, 2 and 5 of the accompanying drawings.

18. A method as claimed in claim 17, and substantially as hereinbefore described with reference to Fig. 7 of the accompanying drawings.

19. A method as claimed in either claim 17 or claim 18, and substantially as hereinbefore described with reference to Figs. 8 and 9, or Figs. 8 and 10 or Figs. 11 and 12 of the accompanying drawings.

20. A method as claimed in any one of claims 17 to 19, and substantially as hereinbefore described with reference to Figs. 6 of the accompanying drawings.

21. Apparatus for measuring, controlling or indicating a motion of a land vehicle relative to an object, comprising an optical correlator device mounted on the vehicle, the correlator device including an optical grating and at least one photo-electric receiver responsive to light modulated by the grating, imaging means to form at least one image of the object on the grating, means for deriving a pair of phase-opposed electrical signals from the correlator device, means for deriving at least one further electrical signal from the phase-opposed signals to represent the motion of the vehicle relative to the object, and means for applying the or each derived signal to means for measuring, controlling or indicating, respectively, the motion of the vehicle.

22. Apparatus as claimed in claim 21, comprising means for deriving a first electrical signal proportional to the speed of the vehicle relative to the ground from the phase-opposed signals, sensing means for providing at least one second electrical signal representing the peripheral speed of a respective rotary or circulatory member supporting the vehicle on the ground, comparator means to compare the first signal with the or each second signal, means for deriving at least one electrical control signal from the comparator means, and means for applying the or each control signal to control means of the vehicle to initiate acceleration or deceleration for the purpose of achieving a predetermined difference between the speed of the vehicle and the peripheral speed of the respective supporting members.

23. Apparatus as claimed in claim 22, wherein the or each supporting member comprises a road wheel of the vehicle, and the or each second electrical signal represents the speed of rotation of the respective road wheel.

24. Apparatus as claimed in any one of claims 21 to 23, comprising means for deriving from the correlator device at least one electrical signal proportional to movement of the vehicle in a direction transverse to the desired direction of travel of the vehicle, and means for applying said signal to steering means of the vehicle.

25. Apparatus as claimed in any one of claims 22 to 24, wherein the optical correlator device comprises optical separating means interposed in the path of light incident

on the grating to provide two images in the polarized light images in the plane of the grating, and displacement means for effecting relative displacement between each of the images and the grating.

26. Apparatus as claimed in any one of claims 22 to 24, wherein the optical correlator device comprises optical separating means interposed in the path of light incident on the grating to provide two images in the plane of the grating of respectively different colour components, of the incident light, and displacement means for effecting relative displacement between each of the images and the grating.

27. Apparatus as claimed in either claim 25 or claim 26, wherein the two images are mutually displaced by half the grating constant.

28. Apparatus as claimed in any one of claims 25 to 27, wherein the means for effecting relative displacement between the grating and the images comprises means for displacing the grating.

29. Apparatus as claimed in any one of claims 25 to 27, wherein the means for effecting relative displacement between the grating and the images comprises means for displacing the optical separating means.

30. Apparatus as claimed in any one of claims 25 to 29, wherein a plurality of optical gratings are superimposed on one another.

31. Apparatus as claimed in any one of claims 25 to 30, wherein the displacement means comprises electro-mechanically operable drive means.

32. Apparatus as claimed in any one of claims 25 to 31, wherein the output signals of the correlator device and the signals from the sensing means are applied to a computer, the resultant of the sideways drift and slip in the direction of travel being calculated by the computer and compared with a predetermined limiting value for the vehicle with due regard to steering displacement of the vehicle supporting members and, on the limiting value being exceeded, the vehicle control means becoming effective to apply corrections to the braking means or drive means, or to the steering means of the vehicle.

33. Apparatus as claimed in any one of claims 25 to 31, wherein the signals generated by the correlator device are responsive to displacement of the images in two mutually perpendicular co-ordinate directions each in a plane at right angles to the line of vision of a driver in the vehicle.

34. Apparatus as claimed in claim 33, comprising summator means, differencing means, and a ratio determining means, a computer and a device for measuring the distance between the vehicle and the object imaged by the correlator device, a pair of phase-opposed electrical signals being derived from the optical correlator in response to relative displacement of the images in each of the two mutually perpendicular co-ordinate directions, each pair of phase-opposed signals being applied to a respective summator means and to a respective difference-forming means, output signals derived from the respective summator means and from the difference-forming means being applied to the ratio determining means, the signal output from the ratio determining means being applied to the computer, and output signals derived from the computer being applied to control means of the vehicle.

35. Apparatus as claimed in claim 34, wherein the output signals derived from the computer are applied to indicator means for indicating information relating to the movement of the vehicle.

36. Apparatus as claimed in any one of claims 21 to 35, wherein the optical correlator device faces towards the rear of the vehicle, the electrical output signal of the correlator device and electrical signals proportional to the speed of the vehicle being applied to comparator means for comparing the signals input thereto, and wherein a warning device is connected to output means of the comparator means.

37. Apparatus as claimed in any one of claims 21 to 36, wherein the optical correlator system is mounted in a housing provided with a displaceable cover, means being provided to retain the cover closed while the vehicle is motionless and to open the cover when the vehicle is moving.

38. Apparatus as claimed in claim 37, wherein the means provided to displace the cover comprise means for introducing gas into the housing while the vehicle is moving.

39. Apparatus as claimed in any one of claims 21 to 38, comprising two optical correlator devices usable simultaneously, a first of which is arranged for measurements along two co-ordinates and is mounted at the front of the vehicle, and the second of which is mounted at the rear of the vehicle and is arranged for measurements transversely to the direction of travel.

40. Apparatus as claimed in any one of claims 33 to 35, wherein the correlator device is mounted behind the windscreen of the vehicle.

41. Apparatus as claimed in claim 36, wherein the correlator device is mounted behind the rear window inside the vehicle.

42. Apparatus as claimed in any one of claims 21 to 41, wherein an optical system is provided in front of the grating of the correlator device to compensate for changes in the distance between the object and the correlator device.

43. Apparatus as claimed in claim 42, wherein the optical system comprises at least

one optical unit for effectively optimizing the image generating capacity in the specified direction of measurement.

44. Apparatus as claimed in claim 43, wherein the optically effective optimizing unit comprises a slit diaphragm in the aperture zone, or in the co-focal zone of the image generating optical system.

45. Apparatus as claimed in claim 43, wherein the optically effective optimizing unit comprises a cross-slit diaphragm.

46. Apparatus as claimed in any one of claims 21 to 45, wherein the optical grating in the correlator device comprises a double-acting polarizing grating.

47. Apparatus as claimed in claim 46, wherein the grating comprises two sandwiched dividers with differently polarizing layers fixedly mounted on carriers in relation to each other.

48. Apparatus for measuring controlling or indicating the movement of a land vehicle, substantially as hereinbefore described with reference to Figs. 1 to 3, or Figs. 1, 2 and 4, or Figs. 1, 2 and 5 of the accompanying drawings.

49. Apparatus as claimed in claim 48, and substantially as hereinbefore described with reference to Fig. 7 of the accompanying drawings.

50. Apparatus as claimed in either claim 48 or claim 49, and substantially as hereinbefore described with reference to Figs. 8 and 9, or Figs. 8 and 10, or Figs. 11 and 12 of the accompanying drawings.

51. Apparatus as claimed in any one of claims 48 to 50, and substantially as hereinbefore described with reference to Fig. 6 of the accompanying drawings.

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Fig. 1

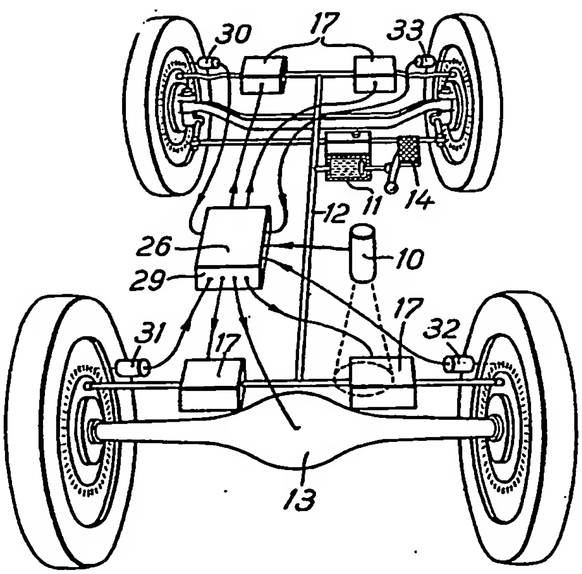


Fig. 2

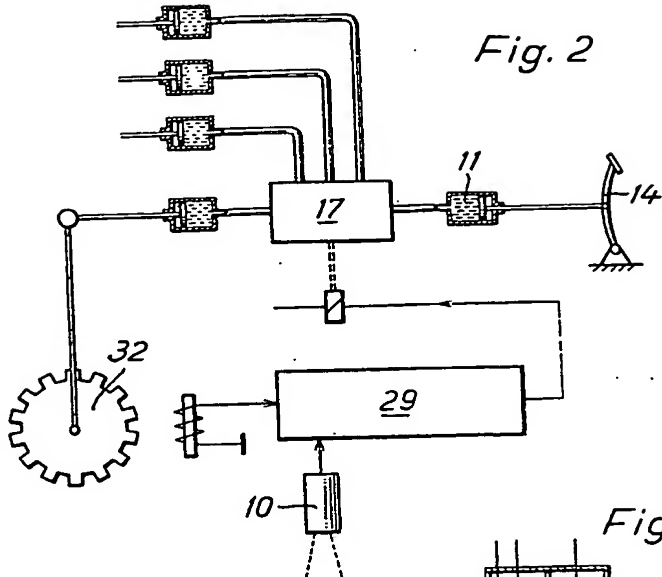


Fig. 6

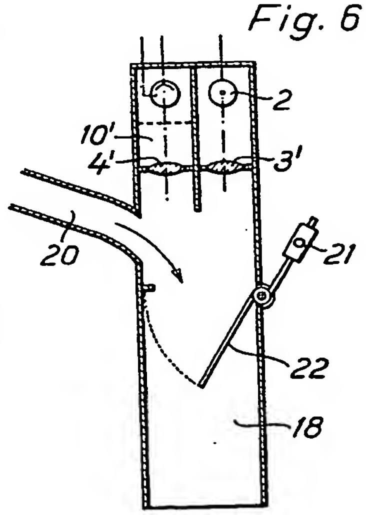


Fig. 5

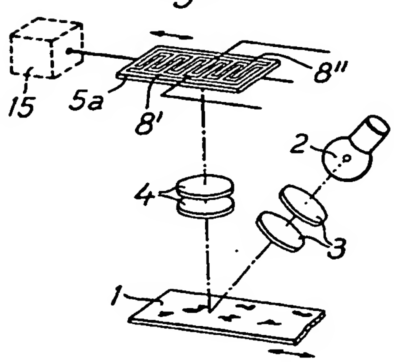


Fig. 3

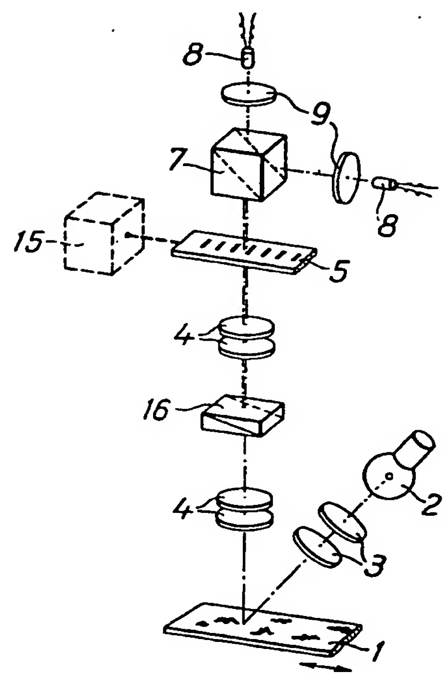


Fig. 4

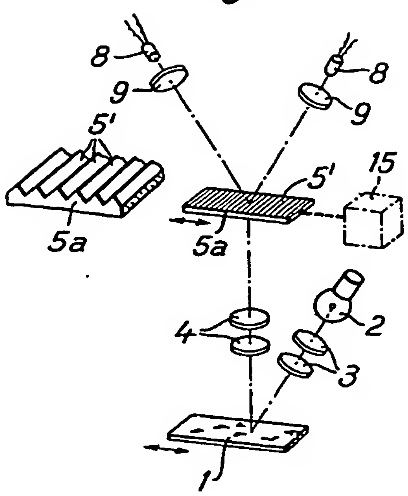


Fig. 4b

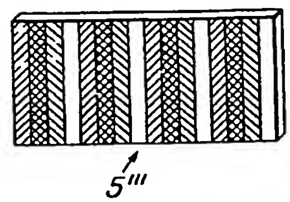


Fig. 4a

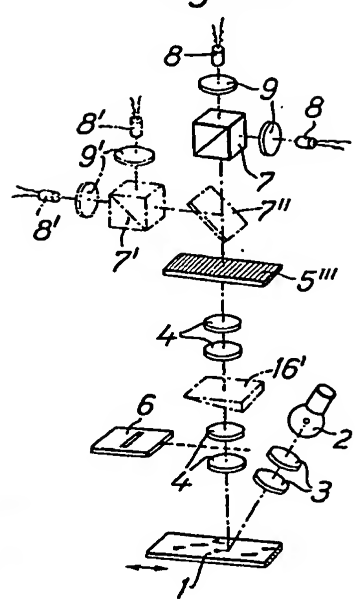
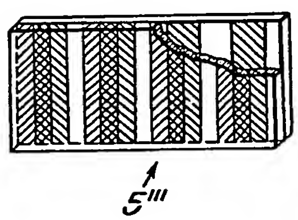


Fig. 4c



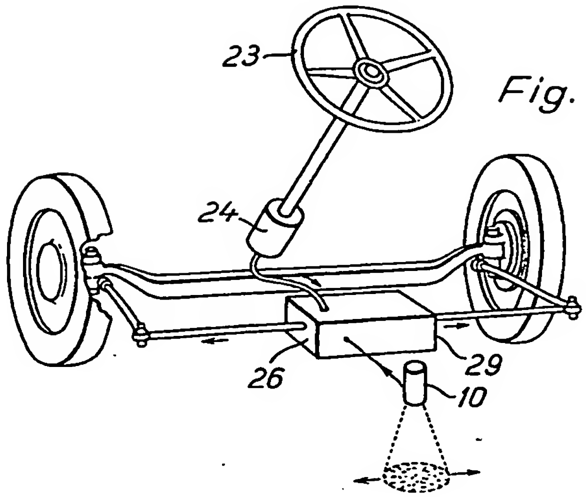


Fig. 7

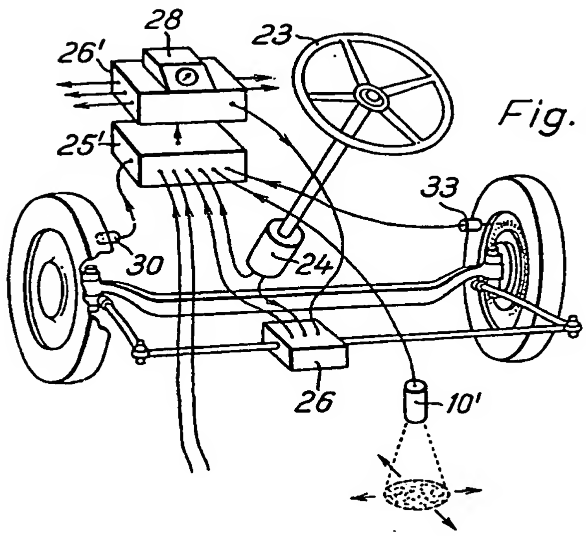


Fig. 8

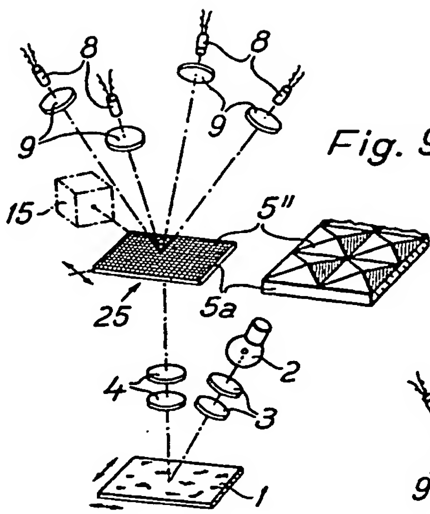


Fig. 9

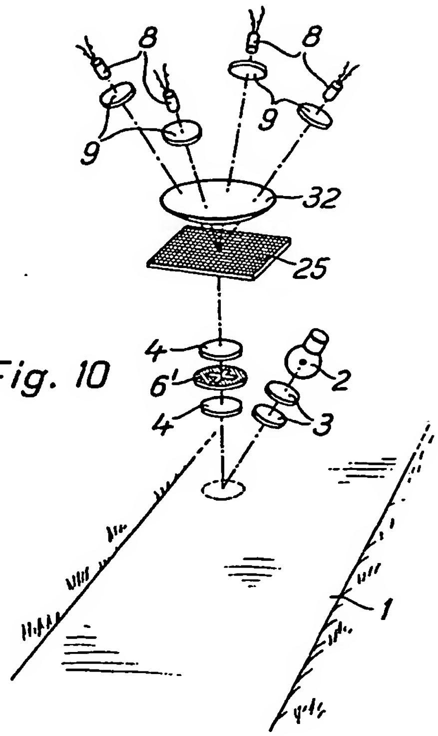


Fig. 10

Fig. 11a

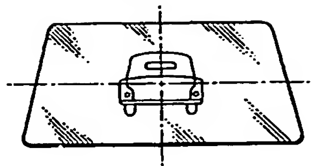


Fig. 11b

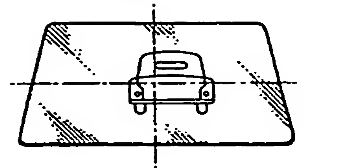


Fig. 11c

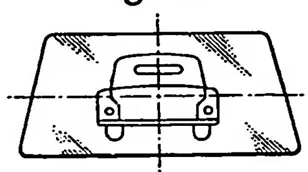


Fig. 11d

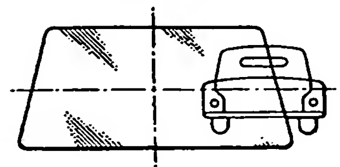


Fig. 11e

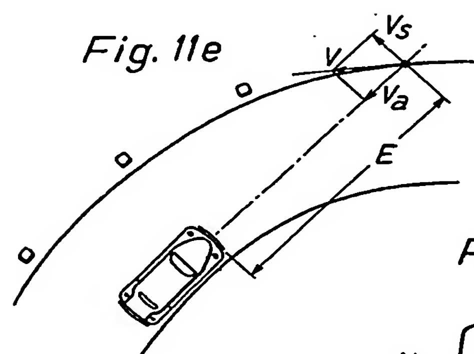


Fig. 11F

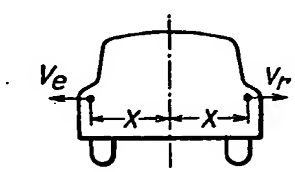


Fig. 11g

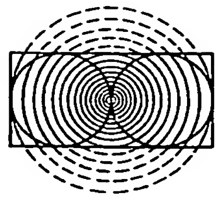


Fig. 12